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AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON ERTS-1 AND SUPPORTING AIRCRAFT DATA

A report of work done by scientists on 5 campuses of the University of California (Davis, Berkeley, Santa Barbara, Los Angeles and Riverside) under NASA Contract No. NAS 5-21827

Progress Report
31 May 1973

UNIVERSITY OF CALIFORNIA

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Chapter 1

INTRODUCTION

Robert N. Colwell

This is the fourth Type 1 Progress Report dealing with work which has been performed under our integrated study by participants on five campuses of the University of California.

We continue to recognize the possibility of achieving two kinds of benefits from this study: (1) some of the ERTS-based resource inventories which we are developing the capability of making should prove to be of direct and immediate benefit operationally to the managers of California's earth resources, even though ERTS-1 was intended to serve only as an experimental system, and (2) resource inventory techniques such as we are developing and testing in California should be applicable, with only minor modification, to many analogous areas in developing parts of the globe.

Because of the continuing contact which we maintain with various types of resource managers throughout the state we are confident that our findings, as reported in the remainder of this progress report, are truly responsive to their needs for timely, accurate information relative to the resources which they seek to manage.

Since the ERTS-1 vehicle has been in orbit for nearly one full year and functioning well, all eight co-investigator groups participating in this integrated study now have a sufficient amount of data taken of the respective test sites to completely carry out their proposed experiments. Thus, it is anticipated that in our next report, the Type 3 Final Report, each co-investigator will present a comprehensive chapter reflecting a full year's work which will show both the advantages and limitations associated with utilizing ERTS-1 and supporting aircraft data.

Chapter 2

REGIONAL AGRICULTURAL SURVEYS USING ERTS-1 DATA (UN640)

Co-investigator: Gene A. Thorley
Contributors: William C. Draeger
James D. Nichols, Andrew S. Benson
Berkeley Campus

2.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

During the past two months work has continued on the development of both manual and automatic agricultural land classification techniques, with particular emphasis being placed on the development of practical interpretation systems which involve both the manual and automated functions. In effect, the aim of this research is to ascertain the optimum integration of the two techniques, using each in those tasks for which it is best suited or most efficient.

Specifically, it appears that general stratifications are probably best performed by human interpreters working with ERTS photos as a preparatory step to actual crop classifications. On the other hand, classification of crops on a field-by-field basis or summaries of specific crop acreages appear to be quite efficiently performed using automated methods. Our efforts at the present time are directed toward perfecting these functions such that a practical methodology for regional application will result.

Work on manual classification has centered around two aspects: (1) the evaluation of stratifications made on various dates to ascertain whether time of year greatly affects stratification accuracy, and

(2) the extension of agricultural land stratification to larger areas surrounding the San Joaquin County test site to determine the applicability of common stratification to larger areas surrounding the San Joaquin County test site to determine the applicability of common stratification criteria to large areas. The research concerning automated classification has concentrated on the classification of individual strata, multidate classification, and problems concerning specific crop acreage estimation.

Chapter 3

USE OF ERTS-1 DATA AS AN AID IN SOLVING WATER RESOURCE MANAGEMENT PROBLEMS IN CALIFORNIA (UN643)

Co-investigator: Robert H. Burgy
Department of Water Science and Engineering, Davis Campus

3.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

Within the interval since the last report, a limited amount of imagery has been added to the data base for water resource applications. Additional data have been collected in field sites to reflect the continuing change of water-related parameters as the season progresses from winter through the spring cycle.

Water quality changes associated with the watershed runoff to rivers and into reservoirs in the study area indicate reduction of sediment and turbidity factors.

The general responses of vegetation to adequate moisture supplies is evident in the imagery. Ongoing work is seeking to gain a means of direct quantification of watershed conditions as related to the runoff produced. In the case of snow covered watersheds, the coverage is as yet incomplete pending the acquisition and analysis of melt-period imagery due later.

Results of the analysis of ERTS-1 coverage of the water resource systems contained in the test site must include the seasonal effects as well as the dynamic responses generated by weather phenomena. This will require the interpretation to be evaluated over a longer time frame. Results of the study will be somewhat slow in development. Additionally the few advantages of appropriate enhancement techniques are being explored to augment the preliminary analyses.

Chapter 4

ERTS-1 DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA (UN257)

Co-investigator: Gene A. Thorley
Contributors: Andrew S. Benson, David M. Carneggie
Edwin F. Katibah, Paul F. Krumpe, Donald T. Lauer
Aileen H. Lineberger, James D. Nichols
Randall W. Thomas, Sharon L. Wall
Berkeley Campus

4.1 INTRODUCTION

Two major wildland studies are being carried out in northern California by the Forestry Remote Sensing Laboratory, namely:

1. Determination and analysis of wildland resource parameters through the use of ERTS-1 and aircraft data in the Feather River headwaters area;

2. Analysis of the California northern coastal zone environment with the aid of ERTS-1 and aircraft data.

Within the separate sections that follow, tasks performed during the period covered by this report and planned for the next reporting interval are documented.

4.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

A simple and inexpensive photographic technique has been developed for producing color composites from black-and-white multiband ERTS-1 imagery. This techniques is discussed below.

The first step in implementing this technique is the acquisition of multiband imagery. Such imagery is commonly obtained either from special multiband cameras, by photographic separation of tri-emulsion color films, or from multispectral scanners similar to the one on the ERTS-1 satellite. Several techniques have been developed which allow multiband images to be combined to form "color composite" images with the intention of facilitating interpretation of these multiple images. ERTS-1 color composites are available from NASA; however the color rendition is limited to simulated Ektachrome Infrared and the time lag between ordering and receiving the product sometimes is quite long. The technique reported herein explores a simple, inexpensive means of producing color composites in various color renditions, with special emphasis on ERTS-1 imagery.

Typical color reversal and color negative films consist basically of three light-sensitive layers. These layers react to blue, green, and red light, and each layer corresponds to a particular dye. If, for

SENSITIVITY	DYE LAYER
Blue	Yellow
Green	Magenta
Red	Cyan

instance, tri-emulsion negative color dilm is exposed to blue light, the blue sensitive layer of the film is exposed. This layer corresponds to a yellow dye produced chemically or introduced during processing, and hence the result will appear yellow on the negative. When tri-emulsion reversal color film is exposed to blue light, the blue sensitive layer of the film is activated; however during processing the two remaining sensitivity layers corresponding to the magenta and cyan dyes are chemically exposed. The originally exposed blue sensitive layer becomes non-functional and the resulting image appears to be a combination of magenta and cyan, or blue. The reactions of color reversal and negative films to red and green light can be explained similarly since red = yellow + magenta, and green = cyan + yellow.

The photographic production of a color composite as described below, relies on the three-layer sensitivity of color film and on the different densities of a single feature as it appears on several discrete bands of multiband black-and-white imagery. Each of the several different bands of black-and-white imagery is photocopied onto the same sheet of color film, each through a different colored filter (in essence a multiple exposure). Depending on which filter is used with each band of imagery, different color renditions may be obtained, thus hopefully enhancing different features. It is not necessary, however, to use three bands of imagery to obtain composite images when using this technique. Two, four or any number of different bands may be combined; however with additional bands the results may be difficult to predict.

The Forestry Remote Sensing Laboratory system used to photographically produce color composite imagery is diagramed in Figure 4.1. The equipment consists of a light table and a copy camera capable of making multiple exposures on a single sheet of film. Other materials include a registration sheet, a set of colored filters, and the multiband imagery. For explanatory purposes the discussion below will consider the process using ERTS-1 imagery, although techniques would be quite similar using any type of multiband black-and-white photography as an input, providing that the separate photographs can be placed in common register.

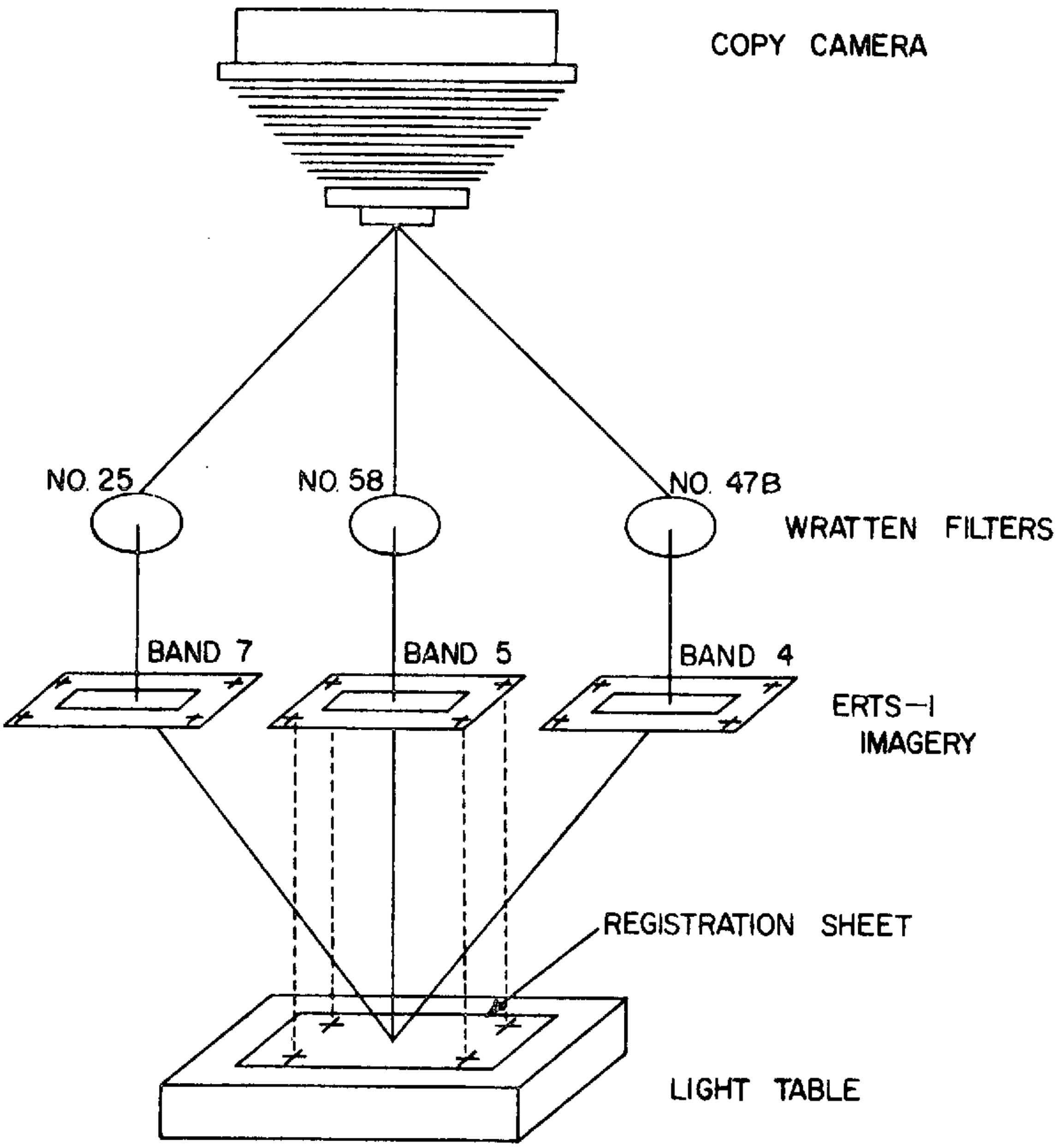

Figure 4.1. This schematic diagram illustrates a simple photographic technique for producing color composite images and employs a copy camera loaded with color film, colored filters, multiband images, a registration sheet and a light table. Note that all three bands are placed separately on the registration sheet for copying.

The most critical step in producing a high resolution color composite is that of registering each of the multiband images with respect to the others. On ERTS-1 imagery all bands of a single data can be registered with respect to one another by aligning the registration marks in the corners of each band of imagery. A registration sheet can be made by transferring the registration marks from one band of a single date of ERTS-1 imagery to a sheet of 8 x 10 inch K&E Stabiline material. The registration sheet is taped down to a light table and, by aligning the marks on the registration sheet with those on each ERTS-1 band, one can position the bands very accurately with respect to one another.

To make the actual composite, each individual black-and-white band of imagery is placed in sequence on the registration sheet and photocopied through the appropriate colored filter. At no time during the making of a composite image is the film advanced. Thus, the image that appears on the sheet of color film as the final product is the result of three separate exposures of ERTS-1 imagery through three different color filters.

It has been found through experimentation that maximum color saturation and contrast can be obtained only if equal or near equal exposures are given to each of the bands. Initially, exposures were determined by trial and error. To aid in future exposure determination, an exposure guide system can be set up in which each band of ERTS-1 imagery taken on a specific date is measured for light transmission through the copy camera-light table set-up. In the Forestry Remote Sensing Laboratory system this is done by measuring the light transmitted through the copy camera with the lens set at a constant aperture. A Gossen Luna-Pro light meter is used to measure the light on the camera's "through-the-lens" ground glass focusing system. Each ERTS-1 band to be used for making a composite is measured separately and then these measurements are averaged. For example, if band 7 measured 6-2/3, band 5 measured 6, and band 4 measured 6-1/3, the average reading would be 6-1/3 (a constant aperture setting is used for all of these readings). Several composites are made using a series of different exposures (bracketing), and the composites with the best exposures are chosen and recorded. Through the use of this procedure with several dates of ERTS-1 imagery, an exposure index can be arrived at whereby it is possible to determine the proper exposure relatively easily. Representative exposure data have been emperically derived and are presented in Figures 4.2 and 4.3 for making a three-band and a two-band composite, respectively. Note from Figure 4.2 that an averaged exposure reading of 6-1/3 would require a shutter speed of slightly less than 2 seconds when using Kodak Ektachrome-X film (ASA 64).

The composite images illustrated in Figures 4.4 and 4.5 were formed on Kodak Kodacolor-X 120 film. Kodak Ektacolor-S film could not be used in this case because of reciprocity effects resulting from the long exposures encountered with the light table currently being used. Therefore it is recommended that the light source used be as bright as possible so that shutter speeds high enough for products like Ektacolor-S can be used. For the production of reversal images Kodak Ektachrome-X film is used with success.

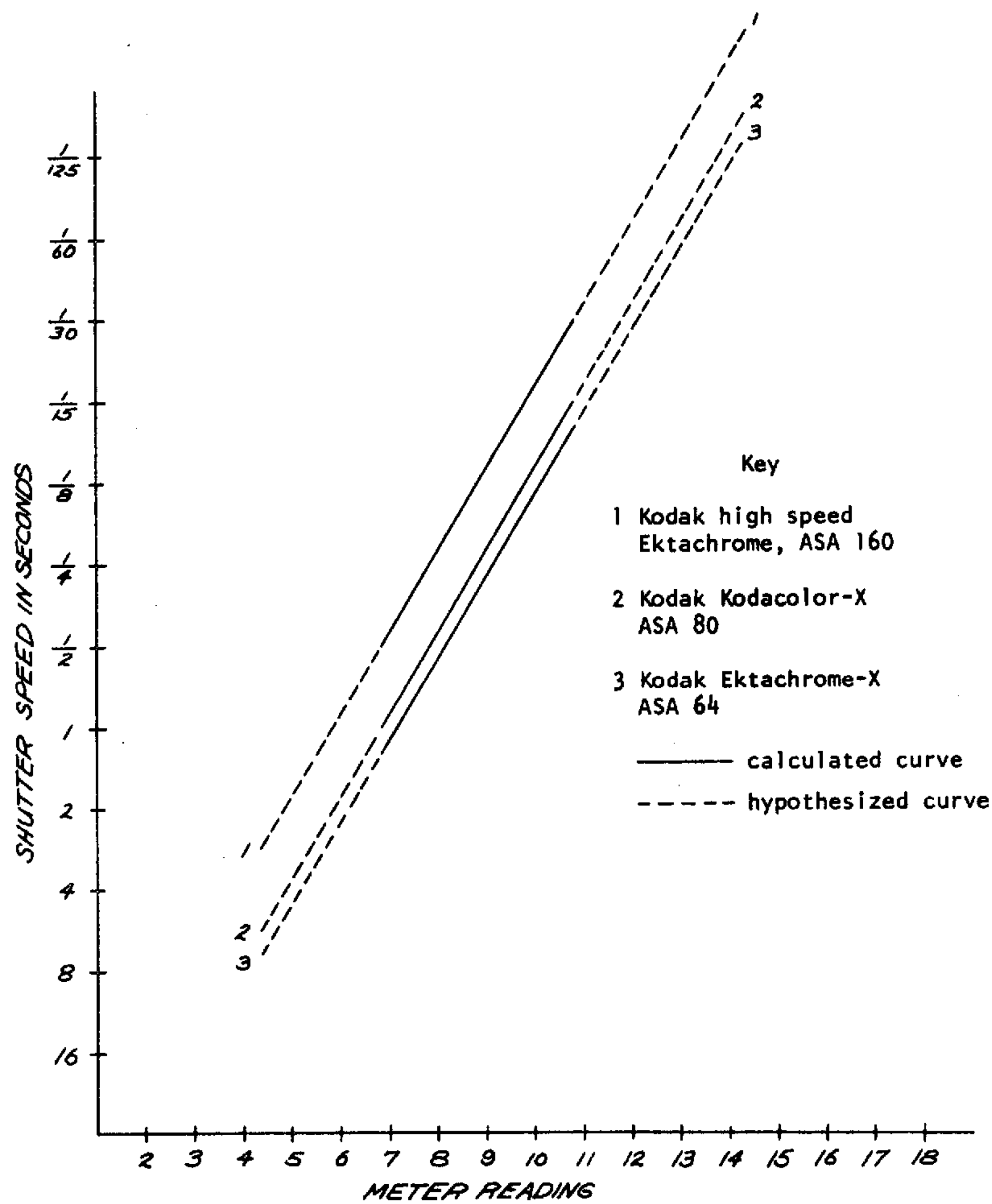

Figure 4.2. Example exposure data (empirically derived) for making a simulated Ektachrome infrared three-band color composite of ERTS-1 imagery using a Wratten 25 filter with band 7, a Wratten 58 filter with band 5, and a Wratten 47B filter with band 4.

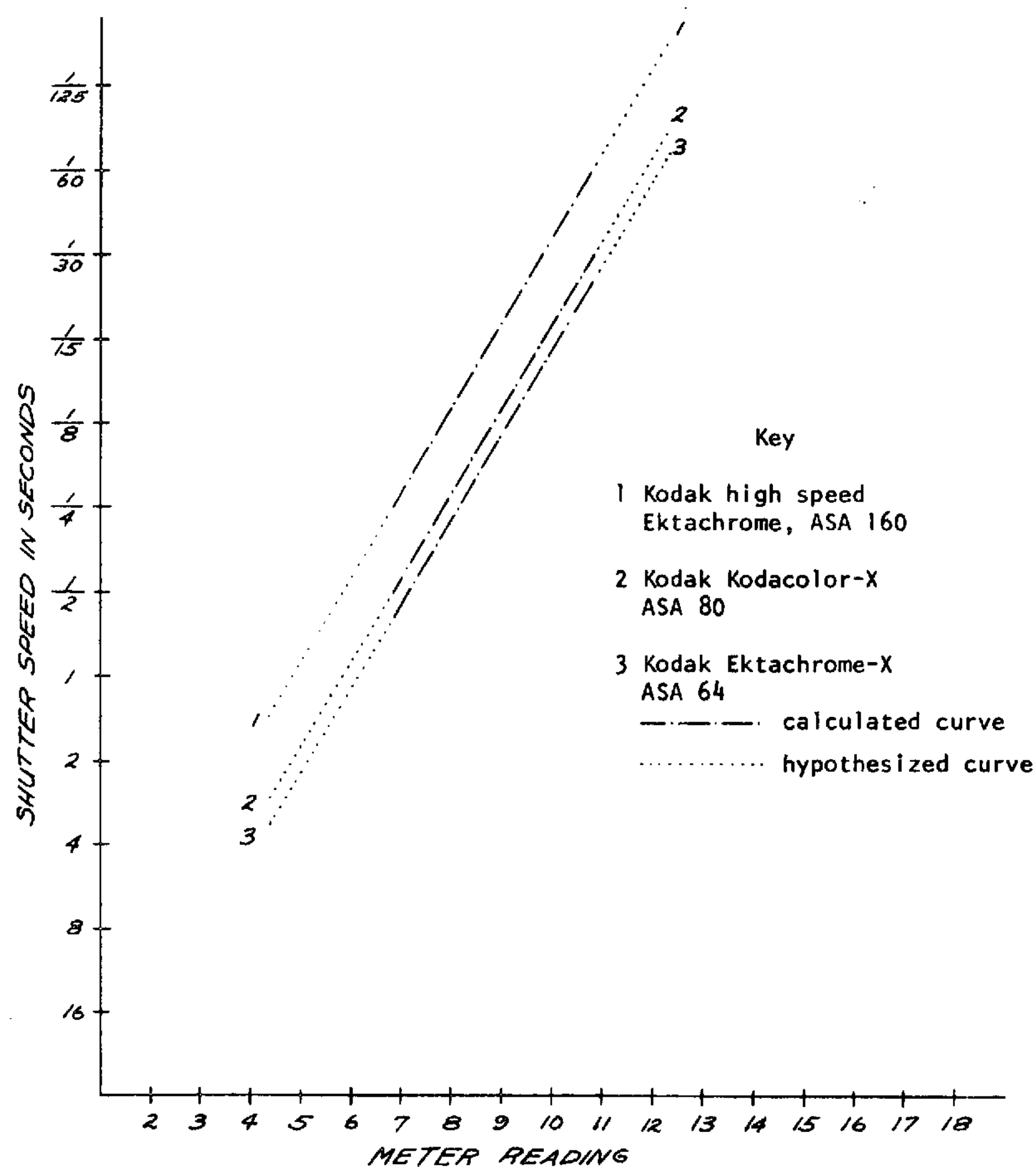

Figure 4.3. Example exposure data (empirically derived) for making a two-band color composite of ERTS-1 imagery using a Wratten 30 filter with band 7 and a Wratten 8 filter with band 5.

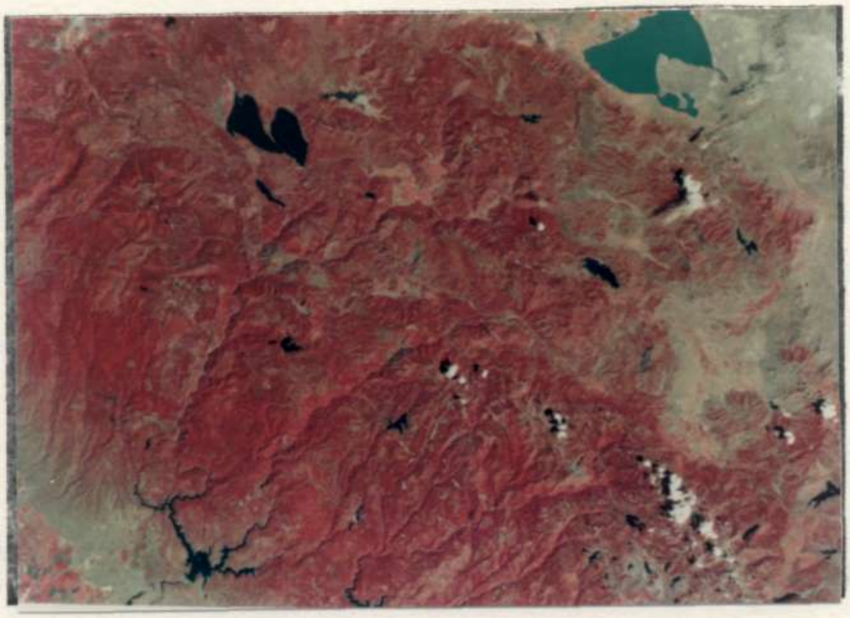

Figure 4.4. Simulated Ektachrome Infrared three-band color composite of the Feather River Watershed in the northern Sierra Nevada Mountains, California, taken from a portion of ERTS-1 imagery (August 31, 1972; N 40-16/W 120-53). Band 7 was photocopied using a Wratten 25 filter, band 5 a Wratten 58 filter, and band 4 with a Wratten 47B.

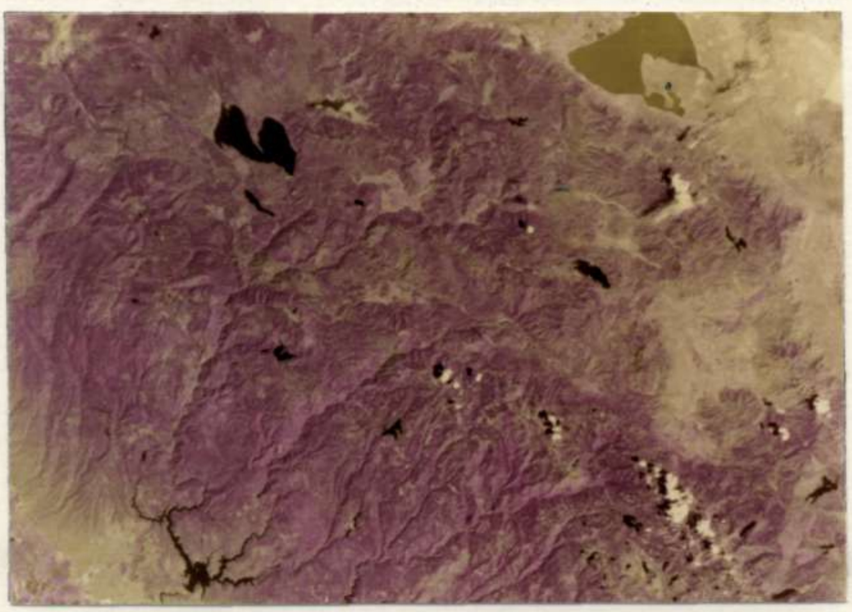

Figure 4.5. Two-band color composite of the Feather River Watershed in the northern Sierra Nevada Mountains, California, taken from a portion of ERTS-1 imagery (August 31, 1972; N 40-16/W 120-53). Band 7 was photocopied using a Wratten 30 filter and band 5 with a Wratten 8 filter.

The best feature of the system described above is its simplicity. Although there are devices on the market which will do the same thing in a much more sophisticated fashion, few systems are as simple and easy to construct as the one described here. Most existing copy camera set-ups can be adapted to this system as can many other conventional camera systems.

4.3 PROGRAM FOR NEXT REPORTING INTERVAL

During the last few weeks of work on this ERTS-1 experiment, emphasis will be placed on bringing to a conclusion all on-going projects being performed in the Feather River watershed and northern coastal zone. For each case study, the work has been designed to show level of accuracy, time requirements and costs associated with doing a particular task with the aid of ERTS-1 data as compared with doing the same task by more conventional methods. The final results of this work, and evaluations of its significance, will be well documented in the final ERTS-1 Type 3 report which is now being prepared.

Chapter 5

ANALYSIS OF RIVER MEANDERS FROM ERTS-1 IMAGERY (UN644)

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Contributor: Richard Lingenfelter
Institute of Geophysics and Planetary Physics
Los Angeles Campus

5.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

During the period covered by this report we have continued to investigate the possibility that significant information on stream flow rates can be obtained from aerial and satellite imagery of river meander patterns by seeking a correlation between the meander and discharge spectra of rivers. Such a correlation could provide the basis for a simple and inexpensive technique for remote sensing of the water resources of large geographical areas, eliminating the need for much hydrologic recording. The investigation of the nature of the meander and discharge spectra and their interrelationship can also contribute to a more fundamental understanding of the processes of both river meander formation and drainage of large basins.

Based on the rivers which we have studied so far we believe that there is significant structure in a meander power spectrum, namely the slopes and magnitudes of the power law segments and the wave numbers at which breaks in these segments occur. It is these characteristic parameters of the meander spectra which we will attempt to correlate with such characteristics of the discharge spectra as the modal discharge and the exponent of the flood recession. Before this can be attempted, however, we must first generate a significantly large number of corresponding meander and discharge spectra on which to base a correlation. This we are in the process of doing.

Chapter 6

USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA (UN 070)

Co-Investigator: John E. Estes
Contributors: L. W. Senger, R. R. Thaman, J. M. Ryerson, S. P. Kraus, D. Cottrell, B. Palmer, D. Brunelle, K. Thaman, T. Soper, F. Evanisko

6.0 INTRODUCTION

The Geography Remote Sensing Unit (GRSU) at the University of California, Santa Barbara is responsible for investigations with ERTS-1 data in the Central Coastal Zone and West Side of the San Joaquin Valley. The nature of these investigations concerns the inventory, monitoring, and assessment of selected parameters that characterize the natural and cultural resources of the two areas. Land use, agriculture (crop identification), drainage networks and basins, landforms, and natural vegetation are the principal subjects for investigation. These parameters are the key indicators of the dynamically changing character of the two areas. Monitoring of these parameters with ERTS-1 data will provide the techniques and methodologies required to generate the information needed by federal, state, county, and local agencies to assess change-related phenomena and plan for management and development.

Previous reporting periods have emphasized an analysis of ERTS-1 data for specific environmental information in selected sites. The purpose of this approach was to identify and develop workable solutions to interpretation and classification problems, in order that "set" methodologies and techniques could be defined preparatory to the construction of the final resource data bases. This phase has been completed, and the present report is concerned primarily with the construction and assessment of completed data bases.

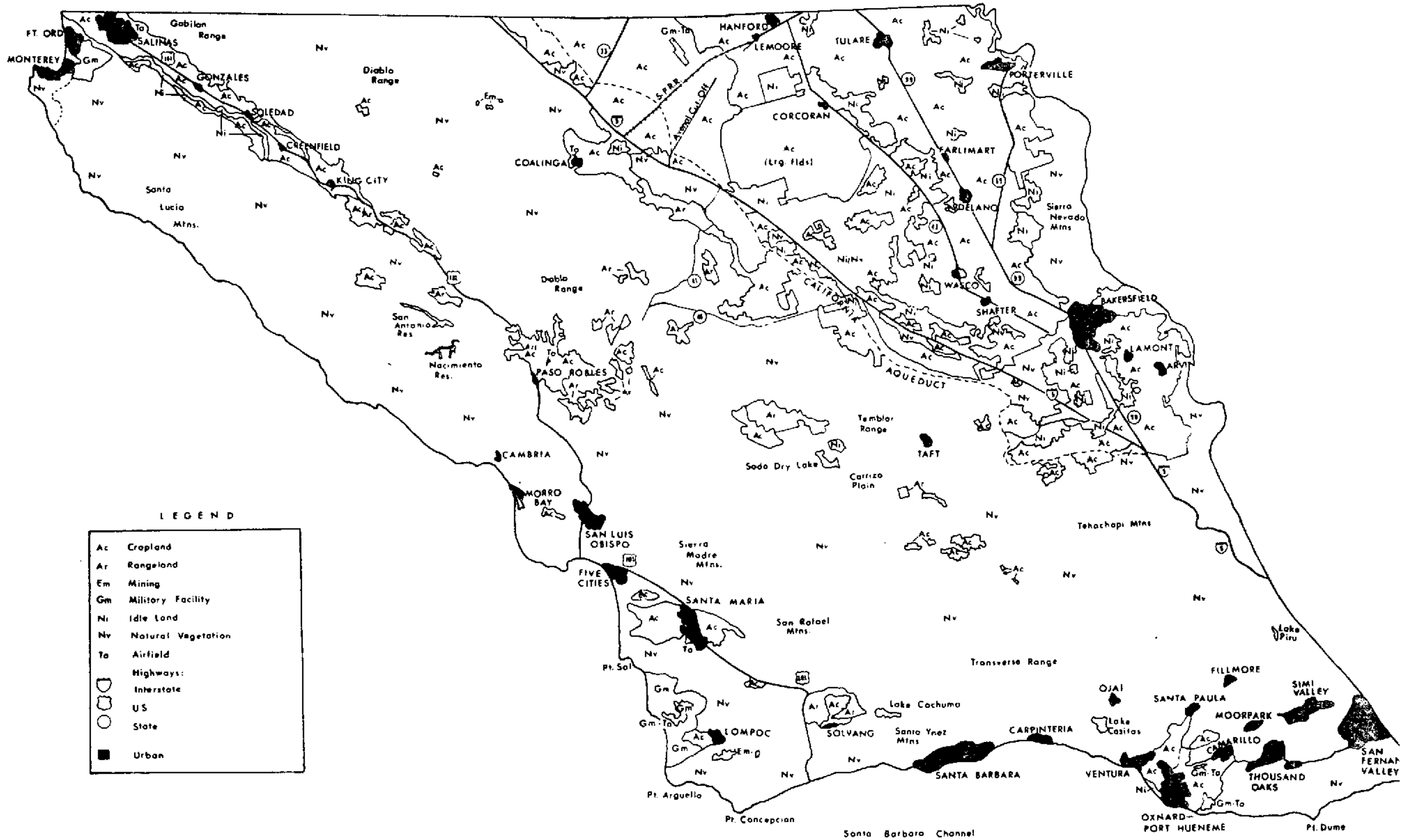
The construction of the various data bases required that two decisions be made: (1) the boundaries of the area for which mapping would be accomplished; and (2) the specific ERTS-1 images which would be used as the data sources for mapping. The mapping area, designated as the Central Region, was finally determined on the basis of including a wide range of environmental habitats, encompassing a sufficiently large area to demonstrate the significance of ERTS-1 type data, and having high quality ERTS-1 coverage. The resultant Central Region test site covers approximately 52,213 square kilometers of land area, with boundaries as follows: extending from Monterey in the extreme northwest; east through Hanford to the Sierra Nevada foothills; south along the Sierra Nevada foothills and across the Tehachapi Mountains to the western end of the San Fernando Valley; west to Point Concepcion, along coastal portions of Los Angeles, Ventura, and Santa Barbara counties; and, finally, north-northwest along the coastline to Monterey. Included within the site are several million people and ten counties (all of Kings, San Luis Obispo, Santa Barbara, and Ventura counties; and portions of Fresno, Kern, Los Angeles, Monterey, San Benito, and Tulare counties). The selection of ERTS-1 images to be used for mapping was based on cloud cover, image quality, and seasonal enhancement of environmental phenomena. The images from which interpretations were performed included the following frame numbers/dates: E 1002-18140/25 Jul 72; E 1018-18010/10 Aug 72; E 1019-18062/11 Aug 72; E 1073-18064/04 Oct 72; E 1074-18123/05 Oct 72; E 1234-18021/14 Mar 73; E 1235-18073/15 Mar 73; E 1235-18075/15 Mar 73; and E 1255-18190/04 Apr 73.

The balance of this report, sections 6.1 - 6.5, are concerned with the progress achieved in the evaluation of ERTS-1 data during this reporting period. Sections 6.1 - 6.4 deal with, respectively, land use, crop identification, drainage and landforms, and natural vegetation. Discussion centers on problems encountered, data analysis, and detailed results. Section 6.5 presents significant results achieved during this reporting period. ERTS Image Descriptors are also included. The key words used to describe the itemized ERTS-1 images represent a preliminary evaluation of information content by GRSU personnel.

6.1 LAND USE

This section represents a final evaluation of ERTS-1 as a source for a land use data base for the entire Central Region test area. The Central Region Land Use Data Base Map (see Figure 6.1), Operational Land Use Classification Key (see Table 6.2), and analysis of the ERTS system presented herein are the result of extensive and concentrated research conducted during previous reporting periods. This final evaluation, however, differs from earlier ones in that: (1) the region is mapped in its entirety: and (2) an overall evaluation of the usefulness of ERTS as a land use identification tool is presented. The sections which follow are concerned with: (1) a brief review of earlier research methodologies and goals; (2) a description of the final construction of a

Figure 6.1. CENTRAL REGION LAND USE DATA BASE



complete test region land use map and operational data base classification key; and (3) an overall analysis of earlier research and the utility and application of ERTS for future land use mapping.

6.1.1 Earlier Research Methodologies and Goals

Evaluation of land use features, using ERTS-1 imagery, during previous reporting periods concentrated on determining the feasibility of ERTS as a data source for land use analysis. The methodology employed involved the use of individual 9.5 x 9.5 inch black-and-white transparencies (MSS bands 4-7) of selected areas within the Central Region test site, as source imagery for the identification, delimitation, evaluation, and mapping of various type land uses. In order to assess the capability of ERTS-1 as a data source for providing meaningful land use information within a working data base context, the investigations focused on identifying specific land use parameters within diversified cultural and environmental (physical) settings. The cultural features examined were: (1) spatial extent and location (both absolute and relative) of urbanized areas; (2) transportation routes and networks; and (3) agricultural development and extent.

Three sets of ERTS-1 MSS band positive transparencies (frame numbers; 1002-18140, North Central Coastal Region; 1073-18064, South Central Coastal Region; and 1019-18062, Central Valley Region) were used initially to evaluate specific land use information potential of ERTS data for diverse environments. For each of the three ERTS-1 frame numbers utilized, MSS bands 4-7 were evaluated for total information content and application to land use studies. The results of these evaluations were summarized in the first three progress reports in the form of individual maps and comprehensive tables.

6.1.2 Land Use Map and Data Base Classification Methodology

The basic methodology employed in constructing a land use map and data base key for the entire Central Region test site involved: (1) determining the boundaries of the area; (2) selecting the optimal imagery for evaluation of land use features; and (3) examining and revising the land use classification scheme developed at the beginning of the project to reflect the interpretability of ERTS-1 imagery.

To insure compatibility of the land use data base map with other environmental maps presented in this report (e.g., natural vegetation, hydrology, etc.), a uniform boundary for the test area was defined. In addition to the previously mentioned North Central Coastal, South Central Coastal, and Central Valley Regions mapped earlier, portions of Ventura and Los Angeles counties, not previously mapped, were included. In order to effectively evaluate the suitability of ERTS-1 as a land use resource identification tool, it was deemed advisable to have a wide range of optimal test area imagery, flown during several periods. Therefore, nine 9.5 x 9.5 inch black-and-white transparencies imaged on various dates were selected. This was done to insure overlapping of multiple frames at any point in the test area, and to allow for analysis of possible seasonal tonal signature differences.

Before actual mapping commenced, each band of each numbered image was evaluated for tone, texture and contrast, and those affording the best potential for land use analysis (usually bands 5 and 7) were used in preparation of the final map. Once the broad Central Region test area boundary had been outlined on clear mylar (acetate), actual land use mapping from the selected 9.5 x 9.5 inch transparencies began.

The procedure involved first examining each image for recognizable land use features. Once these features were identified, their extent was traced onto clear mylar placed over the image. To provide verification of an initial analysis, or further delimit land use features, overlapping images of different dates were then examined. Where additional land use signatures were discovered, this information was traced onto the acetate. In this manner (i.e., the use of overlapping images), a detailed and comprehensive Central Region land use data base map was constructed. Whereas earlier maps relied on imagery from a single data only, the final map made use of multiple date, overlapping imagery.

Preparatory to the commencement of the ERTS-1 program in July 1972, GRSU devised a classification key for use in land use mapping (see Table 6.1). The key was purposely designed with built-in flexibility. Once actual analysis and interpretation of the imagery began, modifications to expand it (i.e., make it more specific), or collapse it (i.e., make it more general), could then be made. After extensive evaluation of various ERTS imagery, using both 9.5 x 9.5 inch transparencies and contact print enlargements from these transparencies, a considerably "collapsed" operational classification key (see Table 6.2) was devised to replace the earlier one.

6.1.3 Overall Analysis of the Utility and Application of ERTS for Land Use Evaluation

This section deals with an overall analysis of the utility and application of ERTS for land use mapping. The discussions which follow

TABLE 6.1. INITIAL LAND USE CLASSIFICATION (July, 1972)

KEY:

General Category, ex. A (Agriculture)
Type within Category, ex. t (tree crops)
Specific Type, ex. c (citrus)
Total Code: Atc

Note that the more specific notation depends upon ability to identify, and that additional types and specific types can be added to the system as they are encountered.

	CODE
AGRICULTURE	A
Grain Crops	Ag - (type)
Horticulture	Ah - (type)
Pasture (improved)	Api
Pasture (unimproved)	Apu
Row Crops	Ar - (type)
Stock farming (beef)	Asb
Stock farming (sheep)	Ass
Stock farming (dairy)	Asd
Tree Crops	At - (type)
EXTRACTIVE	E
Seawater mineral Recovery	Es - (type)
Petroleum production fields	Ep - (type)
Construction materials	Ec - (type)
Mining Operations	Em - (type)
PUBLIC FACILITIES	G
Govermental-administrative	Ga - (type)
Govermental-military	Gm - (type)
Cemeteries	Gc
Protection - Police & Fire	Gf - (type)
Hospitals	Gh
Prisons	Gp
Waste disposal (solid & liquid)	Gd - (type)
Education	Ge - (type)

TABLE 6.1 (Continued)

	CODE
PARKS & RECREATION	P
Campground	Pc
Golf Course	Pg
Park	Pp
Stadium	Ps
Marinas	Pm
Resort	Pr
INDUSTRIAL	I
Power plant (fossil, hydro, nuclear)	Ib - (type)
Warehousing	Id - (type)
Commercial fishing (docking & Canneries)	If - (type)
Port facilities	Ip
Shipbuilding & repairs	Is
Heavy manufacturing	Ih - (type)
Light manufacturing	Il - (type)
Saw mills (or pulp)	Iw
Power substation & Transmission	It
TRANSPORTATION	T
Airports	Ta - (type)
Highways (roads, etc.)	Th - (type)
Railroads & Yards	Tr - (type)
Canals	Tc - (type)
COMMERCIAL	C
Clustered	Cc - (type)
Strip	Cs - (type)

TABLE 6.1 (Continued)

	CODE
RESIDENTIAL	R
Single family	Rs
Multi-family	Rm - (type)
NON DEVELOPED	N
Natural Vegetation	Nv - (type)
Idle land	Ni - (type)
Barren Land	Nb - (type)
Water Bodies	Nw - (type)

TABLE 6.2. OPERATIONAL LAND USE CLASSIFICATION (May, 1973)

KEY:

General Category, ex. A (Agriculture)
Type within Category, ex. c (crops
Specific Type, ex. g (grain)
Total Code: Acg

General Category	Code	Comments
AGRICULTURE	A	
Field Crops	Ac - (type)	may include row type (r); grain type (g); and tree/orchard (t). Additional sub-types could be added.
Range Areas	Ar - (type)	grasslands differentiated from surrounding vegetation and often showing signs of fencing (square borders). May include improved (i) or unimproved (u).
EXTRACTIVE	E	
Mining Operations	Em - (type)	may include open pit (o), etc. and additional sub-types.
Petroleum Production Fields	Ep	Usually identified by maze of crossing access roads
PUBLIC FACILITIES	G	
Govermental- military	Gm - (type)	may include air bases (ta), army installations (indicated by Fort ____), etc.
PARKS AND RECREATION	P	
Golf Course	Pg	readily identifiable on MSS Band 7 if of eighteen hole variety
Marinas	Pm	identifiable due to geometrical signature along coastlines
INDUSTRIAL	I	
Port Facilities	Ip	same as Pm, but larger
TRANSPORTATION	T	
Airports	Ta	signature depends on locational context to other features and runway material.

TABLE 6.2 (Continued)

General Category	Code	Comments
Highways (roads, etc.)	Th*	*roads are normally mapped using their federal, state or county number (i.e. 101 rather than the code).
Railroads	Tr*	*railroads are usually mapped using the abbreviations for their operating company (i.e. S.P.R.R. - Southern Pacific Railroad Co.).
Canals	Tc*	*canals are normally identified by name (i.e. California Aqueduct).
URBAN	U*	*urban areas, undifferentiated between commercial and residential. Residential are normally identified by the city name (i.e. OJAI) in bold type and their extent shaded in.
NON-DEVELOPED	N	
Barren Land	Nb	includes extensive sand or bare rock areas
Idle Land	Ni	land within or bordering agricultural or urban areas which has been cleared but not used for commercial purposes.
Natural Vegetation	Nv	see natural vegetation data key and map for specific vegetation associations.
Water Bodies	Nw* - (type)	*normally indicated by lake (l), river (r), or ocean (o) name on map.

are concerned with use and applications in: (1) determining extent and location (both absolute and relative) of urbanized areas; (2) locating and tracing transportation routes and networks; and (3) delimiting agricultural extent and development.

It should be pointed out that the ability to identify and delimit land use features is very dependent on several major factors, including: (1) ERTS image resolution and quality; (2) seasonal variations; and (3) the location of the particular feature in relation to others. Often a land use feature exhibits a slightly different tonal or textural signature when one or more of the above factors changes. For instance, U.S. 101, a major four-lane highway, was inconspicuous and difficult to trace between Santa Barbara and Santa Maria on ERTS image number E 1073-18064 for October, 1972. However, five months later, using ERTS image number E 1235-18075 for March, 1973, the highway was easily traced. The reason for the variation between the two frames of the same area, was that the October 1972 image was taken at the end of the southern California day season, while the March 1973 image was taken after unseasonably heavy rainfall. Thus U.S. 101, with its light tonal signature, blended completely with the light toned surrounding grassland during the earlier period, but contrasted sharply against the dark, even-textured moist grassland in the latter. Therefore, the following analysis, while applicable to the ERTS imagery used, may be subject to futher modification in the future.

Urban Areas

In addition to extensive macro-scale evaluations made of individual urban concentrations in the three regional sectors analyzed earlier (see Table 6.1 "Evaluation of MSS Bands 4-7: Urban Concentrations" for each of the first three progress reports under section 6.1 LAND USE), a micro-scale analysis of the application of ERTS imagery to accurately delimit and measure urban areal extent was also conducted.

The results of both the macro- and micro-scale analysis would seem to indicate that ERTS is an excellent general purpose data source for the identification of urban area location. This is with particular reference to populated areas of over 4,000 inhabitants. The final map (see Figure 6.1) includes forty-two urban areas (see Table 6.3), with Atascadero (pop. 10,290) and Carmel (pop. 4,525), the only cities/areas over 4,000 population which were not identified on the imagery used. In part, this failure was due to inadequate tonal contrast in the former, and to constant cloud cover over the latter. Identification, in most cases, was facilitated by locating the characteristic light grey tonal signature and mottled texture of the urban area, as contrasted with the different signature of surrounding non-urban areas. The contrast was best defined in areas of extensive agricultural production (i.e., the San Joaquin/Central Valley), and poorest in areas surrounded by extensive natural vegetation, such as grassland or sage/scrub (i.e., San Luis Obispo). Also, location along transportation (road) networks further aided in identification.

While ERTS-1 has proven a useful tool in the identification of urban area location, its value in determining actual urban areal extent is still to be proven. The previously mentioned micro-scale analysis, conducted in an earlier reporting period, compared known area figures from 1971 NASA high flight (scale 1:120,000) and predicted area

TABLE 6.3. URBAN AREA POPULATION DATA

CITY	COUNTY	AREA POPULATION*
Arvin	Kern	5,199
Bakersfield	Kern	69,515
Camarillo	Ventura	19,219
Cambria	San Luis Obispo	1,716
Carpenteria	Santa Barbara	6,982
Coalinga	Fresno	6,161
Corcoran	Kings	5,249
Delano	Kern	14,559
Earlimart	Tulare	3,080
Fillmore	Ventura	6,285
Five Cities (including Arroyo Grande, Grover city, Nipomo, Oceano and Pismo Beach)	San Luis Obispo	27,840
Fort Ord	Monterey	26,128
Gonzales	Monterey	2,575
Greenfield	Monterey	2,608
Hanford	Kings	15,179
King City	Monterey	3,717
Lamont	Kern	7,007
Lemoore	Kings	4,219
Lompoc	Santa Barbara	25,284
McFarland	Kern	4,177
Monterey (including Seaside and Pacific Grove)	Monterey	77,819 (est.)
Moorpark	Ventura	3,380
Morro Bay	San Luis Obispo	7,109
Ojai	Ventura	5,591
Oxnard-Pt.Hueneme	Ventura	85,520 (est.)
Paso Robles	San Luis Obispo	7,168
Porterville	Tulare	12,602

TABLE 6.3 (Continued)

CITY	COUNTY	AREA POPULATION*
Salinas	Monterey	58,896
San Luis Obispo	San Luis Obispo	28,036
Santa Barbara (including Goleta and Montecito)	Santa Barbara	128,215 (est.)
Santa Maria	Santa Barbara	32,749
Santa Paula	Ventura	18,001
Shafter	Kern	5,327
Simi Valley	Ventura	61,327
Soledad	Monterey	6,843
Solvang	Santa Barbara	2,004
Taft	Kern	4,285
Thousand Oaks	Ventura	36,334
Tulare	Tulare	16,235
Ventura	Ventura	57,964
Visalia	Tulare	27,482
Wasco	Kern	8,269

*1970 U.S. Census Bureau figures.

measurements from enlarged ERTS imagery (approx. scale 1:150,000). The results showed the latter to be relatively inaccurate, with an error of at least ±10 percent for ten sites that were sampled. The major source of error on ERTS occurred at the boundaries of the study areas, where urban and non-urban features merge as a result of population/building density decreasing towards the perimeter. However, this may have been the result of limited resolution and also of seasonal variation (since August 1972 imagery was used).

Initial examination of March 1973 imagery, following an extensive rainy season, shows differences both in urban signature and extent, with boundaries of the test areas better defined than in the August 1972 imagery. A re-evaluation of ERTS as a data source for urban extent analysis, using the improved March 1973 imagery, may yield more accurate results.

ERTS-1, then, is a valuable data source for urban area identification, and a possible tool for accurate delimitation of urban areal extent. Unfortunately, attempts to identify smaller land use features (i.e., commercial and residential structures) within urbanized areas using ERTS have proved unsuccessful. Regardless, there are significant planning implications of applying the ERTS synoptic view as a monitoring tool for gross urban expansion and development.

Transportation Routes and Networks

An extensive evaluation of individual transportation features (e.g., highways, secondary roads, canals, airports, railroads, etc.) for the various test region sectors is contained in earlier reports under Table 6.2 "Evaluation of MSS Bands 4-7: Transportation Features." In general, ERTS has proven an accurate tool in locating, identifying, and tracing various transportation features, especially in those areas of extensive agricultural production where contrasts are greater. Thus, two-lane and four-lane highways are clearly traced in the agriculturally rich San Joaquin and Salinas Valleys, as are other transportation features such as the California Aqueduct (especially on bands 6 and 7). However, as with urbanization, in locations with extensive grassland or natural vegetation regime characteristics (i.e., most of the Coastal Central Region), the typical light tonal, linear signature of highways and railroads readily blends with the similar light-toned, mottled texture of surrounding features. In addition, the relatively narrow width of transportation features, such as roads and railroads, renders their identification even more difficult given the resolution capabilities of ERTS. Furthermore, seasonality has a marked effect on signature response, especially where tonal contrasts between vegetative features and transportation arteries are highlighted. The earlier example of U.S. 101 between Santa Barbara and Santa Maria illustrates this point.

Regarding other transportation features (e.g., airports and railroads), the results have been less encouraging. In the case of airports, the main factors seem to be runway construction material, size of the facility, and contrast with surrounding land uses. The extensive concrete runway surfaces of Vandenburg and Oxnard Air Force Bases and Lemoore and Pt. Mugu Naval Air Stations, were easily identified and mapped. However, the only civilian airports delimited were at Salinas, Paso Robles, Santa Maria and Coalinga where, for still undetermined reasons, there was good contrast between them and their surrounding environments. Unidentified were several airports with 4,000'+ runways, including San Luis Obispo, Santa Barbara, Monterey, King City, Oxnard-Ventura, Shafter, and Bakersfield-Meadows.

Railroads proved even more difficult than airports. The only trackbed identified was a S.P.R.R. spurline from Coalinga toward Hanford, through extensive agricultural land. Here contrasts with the surrounding environment facilitated identification. The main reasons for the inability to identify other tracks, including coastal and Central Valley mainlines, are: (1) the narrowness of the trackbed; and (2) the common procedure of constructing highway and railroad right-of-ways adjacent to one another, so that the latter's trace blends with the former's.

In summary, ERTS has utility and applications as a resource tool to accurately identify, locate, and trace transportation networks. It should prove particularly relevant for highway planning and spatial network inventory analysis by federal, state, and county agencies. Furthermore, in conjunction with urban area uses, it could substantially aid not only in identifying existing networks, but in locating and evaluating future routes.

Agriculture

One of the most successful applications of ERTS-1 to land use identification in the Central Region test area was in agriculture.

While little success was experienced in attempts to accurately identify individual crop types, using tonal/textural signatures, results were achieved in: (1) identifying agricultural areas; and (2) accurately measuring their extent. While it has not been possible thus far to identify individual crop types within the Ac classified areas (or to further sub-divide between row and orchard crops on a gross scale), it was possible to recognize land now in agricultural use owing to rectangular field signatures and/or the presence of extensive, regular vegetation tone/texture. Ni land was identified on the basis of the absence of field boundaries and the presence of uniform vegetation/soil tonal responses. However, it should be noted that it is possible that small areas of fallow land may have been included in the Ni classification, where field boundaries blended with the similar light signature of the bare soil.

Regardless, a high degree of mapping accuracy is possible, and the following specific example is an indication of the reliability of the rest of the mapped data for the study area. During the summer of 1972, an agricultural land use map of a portion of Kern County (radiating from Bakersfield N, W, & S) was constructed from 1971 NASA high flight 70 mm black-and-white negatives (enlarged to a scale of 1:290,000), and crosschecked with 1:120,000 scale color infrared imagery. This was sent to the Kern County Water Agency (K.C.W.A.) for verification of agriculture acreage estimates. When K.C.W.A. figures were received, the same area was mapped from ERTS-1 with the following results:

Source	Agriculture Acreage Estimate (acres)
1. NASA High Flight (70mm) - 1971	753,369
2. K.C.W.A. - 1971	795,280 (including fallow)
3. 1969 Crop Survey (Kern County)	746,104 (excluding fallow)
4. ERTS-1	748,050

For future agricultural land use feature investigation, ERTS shows excellent possibilities as a relatively inexpensive, highly accurate tool for delimiting and measuring agricultural development in the Central Region test site. Particularly relevant would be its use by federal, state, and county agriculture officials to measure changes in agricultural extent, both on a regional and local basis. In this way, contraction of established areas (such as the Salinas Valley, East Side of the San Joaquin Valley, and the Oxnard Plain) could be measured, where agriculture is interfaced with urban expansion and competes for available land. Conversely, ERTS would prove extremely valuable for monitoring and measuring agricultural expansion on the West Side of the San Joaquin Valley, now that adequate water is available via the recently completed California Aqueduct.

6.1.4 Summary

Based on the research which has been accomplished, ERTS-1 data will have useful applications for the identification and measurement of land use features at a macro-level. While it does not lend itself to micro-analysis and identification of very small features (i.e., urban residences), ERTS-1 does offer valuable potential as a gross feature (i.e., urban areal extent, transportation features, agricultural acreage, etc.) regional analysis planning tool.

The potential value and magnitude of the synoptic view afforded by ERTS, as illustrated by the Central Region Land Use Data Base Map, for regional planning is evident, both in the extent (52,213 square kilometers) and the nature (transcending artificially created political boundaries) of the coverage. Land use information is essential for determining present levels of land development and evaluating future directions that development should take. These considerations are becoming increasingly regional in scope, and ERTS provides a mechanism whereby regional planning efforts can be coordinated on a large scale. As this trend becomes more firmly established, ERTS-1 type data for land use should play a more substantial role in the planning process and facilitate regional level decision-making activities.

6.2 CROP IDENTIFICATION

Interpretation of vegetated/non-vegetated field conditions along Central Valley transects from ERTS-1 data is nearing completion. These data will then be examined to determine the discrete periods during the year when a field is in a vegetated condition, as well as the specific months at which this occurs. These discrete temporal tonal patterns (for vegetated conditions) will be correlated with a conventional crop calendar to identify characteristic tonal signature patterns that may be directly associated with the growing season of a specific crop type.

At the completion of this investigation, it will be possible to make several conclusions concerning: (1) types of crops for which this type of technique is particularly suitable; (2) the amount of error which might be anticipated if the technique is made operational; (3) any peculiarities of crops or field conditions that restrict the use of the technique; and (4) the times of the year when it may be expected that image acquisition will be difficult to accomplish due to cloud cover, haze, or other atmospheric disturbances.

6.3 DRAINAGE AND LANDFORM MAPPING

To more fully evaluate the potential of ERTS-1 data, drainage and landform characteristics of the Central Coastal Zone and San Joaquin Valley are in the process of being mapped. These phenomena are significant in relation to: (1) watershed management; (2) determination of potentially hazardous areas; (3) identification of possibly unique environmental features or habitats; and (4) assessing the potentials and limitations for planned area development.

The landform study is nearing completion. The major objectives will be to determine the types of landform features that can be identified and the accuracy with which each can be located. A significant result which has already emerged from the beginnings of the landform study concerns the identification of a possible continuation, previously unknown, of a major fault lineament; this was discussed in the last reporting period. Drainage mapping has been completed and is reported on in the following sub-section.

6.3.1 Drainage Networks and Basins

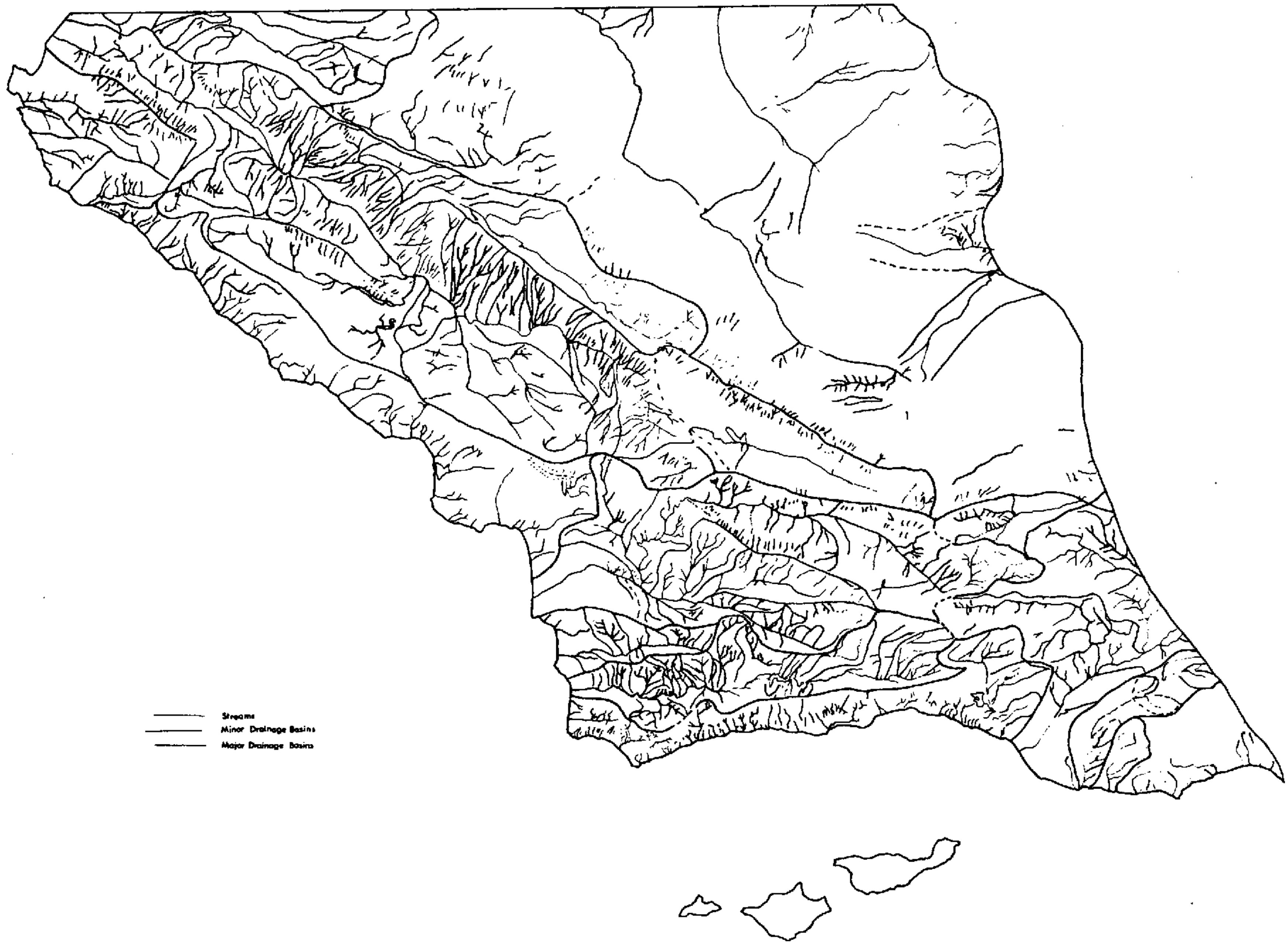
As stated in prior reports, preliminary analysis of ERTS-1 data indicated a definite potential for compiling drainage network and basin maps. In order to more fully evaluate this initial hypothesis, drainage characteristics of the Central Region were mapped from ERTS-1 data. This information was then compared to 1:250,000 U.S.G.S. topographic maps to determine the accuracy of mapping and the feasibility of using ERTS-1 data to update existing small scale drainage maps.

The methodology for mapping drainage characteristics consisted of four basic steps: (1) tracing all clearly defined stream flowlines on the ERTS-1 images; (2) delimiting drainage basins on the basis of the stream flowlines and topographic characteristics; (3) delimiting drainage basins on 1:250,000 U.S.G.S. topographic maps; and (4) comparing the ERTS-derived drainage data with data derived from the topographic maps. Mapping was performed at actual ERTS-1 scale, using acetate overlays. Interpretation was facilitated by utilizing different dates of ERTS-1 imagery for the same area, since this procedure provides a capability for stereoscopic viewing.

The accuracy of identifying drainage networks and basins from ERTS-1 data was determined by comparing three selected areas on 1:250,000 topographic maps with corresponding areas on the completed ERTS-1 Central Region Drainage Data Base map (see Figure 6.2). The comparison indicated that major streams (3rd order or greater) could be identified with 100% accuracy, while the accuracy for minor streams (2nd order or smaller) dropped to approximately 77%. There were no problems in accurately identifying drainage basins for the areas compared; stereoscopic viewing made it a simple task to delimit these features from ERTS-1 data.

The major difficulties in interpreting drainage data from ERTS-1 imagery were encountered in areas of: (1) arid environments; (2) valley

Figure 6.2. **Central Region Drainage Data Base**



bottoms; and (3) slopes where a large number of streams flow into a higher order stream system. Arid environments presented the problem of deciding upon the proper flowline to trace. Water flow is so intermittent that the course of a given stream channel may vary considerably, depending upon the amount of rainfall received in a particular season. In the case of valley bottoms (such as may be found in the San Joaquin Valley), field patterns associated with agricultural land usage exhibit a tendency to mask natural lines of water flow; inferences must be made in these situations. Finally, certain areas of slope (particularly steep ones) posed problems related to storm conditions. Heavy water flow during storms causes stream channels to vary their courses, and it is often difficult to establish what the proper flowline should be.

Despite the problems cited, ERTS-1 imagery appears to be a very useful source for mapping drainage networks and basins. In this representative study, major stream courses could be delimited with 100% accuracy and, in several instances, flowlines could be identified on ERTS-1 imagery that did not appear on 1:250,000 topographic maps. Drainage basins could be delimited with no problems. Consequently, it should be feasible to employ ERTS-1 data for the construction of new drainage maps or to update existing ones. This would be an invaluable aid to government agencies charged with this responsibility, and to those groups involved in watershed management and planning.

6.4 VEGETATION MAPPING OF THE CENTRAL COASTAL ZONE AND THE WEST SIDE OF THE SAN JOAQUIN VALLEY

In previous reporting periods, ERTS-1 data were shown to have considerable utility for the accurate mapping and interpretation of natural and cultural vegetation communities. The present investigation deals with the completion of a vegetation data base map for the entire Central Region test site.

The objectives of this final phase in the evaluation of ERTS-1 imagery for the inventory and mapping of vegetation resources were three-fold: (1) to extend and test the methodologies and classification systems that were developed in previous studies of smaller and more restricted test sites; (2) to determine if any additional problems might be encountered when mapping a more extensive and diverse vegetational unit; and (3) to complete the vegetation data base for the entire test site so that it may be used as a bench mark against which future vegetational changes or studies can be evaluated.

6.4.1 Methodology

The methodology utilized for this study involved: (1) modification of the vegetation classification system developed in initial phases of this ERTS-1 investigation, so that it would be more applicable to the broader scale mapping procedures required for the Central Region test site; (2) reorientation of interpretation procedures for mapping off of the 1:1,000,000 9.5 x 9.5 inch ERTS-1 images, particularly the selection of an appropriate mapping cell size; (3) actual vegetation mapping off of the black-and-white 9.5 x 9.5 inch transparencies, utilizing different bands and different dates to maximize the advantages afforded by the multiband and multidate dimensions of ERTS-1 imagery; and (4) an evaluation of the completed data base map, interpretation techniques, and the utility of these data.

The classification systems utilized for the previous studies of ERTS-1 imagery for vegetation mapping in the coastal and arid zones of the test area are listed below in Tables 6.4 and 6.5. These classification systems were appropriate for both of the previous studies, owing to their focus on smaller areas and the dependence on five-times (5x) enlargements of selected portions of the ERTS-1 images for the actual interpretation. However, for the completion of the vegetation mapping for the entire test site it was necessary to integrate these two systems into a composite classification system. In addition to integrating the two systems, it was also necessary to collapse some of the very specific hierarchical categories into a broader classification more suited to broad scale regional mapping. An example is the combination of associations such as mesquite, lowland types, sage brush, and saltbush into the single classification of desert scrub. It was necessary to add one additional vegetation category, "scrub grassland," owing to considerable areas where the dominant vegetation types were comprised of almost equal concentrations of scrub and grassy species. Agriculture, Urban and Waterbodies were also included to provide for continuous (100%) mapping of the entire region. The classification system as used on the finished map is shown in Table 6.6.

It was felt that these categories would adequately account for the combination of vegetation associations that are encountered in the region. Some of these associations or categories vary from site to site in species composition. However, in almost all cases, the site characteristics and physiognomy of the vegetation within given

TABLE 6.4. NATURAL VEGETATION CLASSIFICATION UTILIZED FOR PRELIMINARY ERTS-1 MAPPING OF COASTAL SITES

Plant Community	Code
I. Aquatic	
A. Marine (Aquatic)	M
1. Nearshore (Kelp and seaweed)	Mn
2. Intertidal	Mi
B. Freshwater (Aquatic)	Fw
C. Marsh	Ma
1. Salt Marsh	Ma_{sm}
2. Freshwater Marsh	Ma_{fm}
II. Terrestrial	
A. Barren	Ba
B. Strand	Sr
C. Grassland	G
1. Coastal Prairie	Gcp
2. Valley Grassland	Gvg
3. Meadows	Gme
D. Woodland-Savanna	Ws
E. Scrub	S
1. North Coast Shrub	Snc
2. Coastal Sagebrush (soft chaparral)	Scs
3. Cut-over Forest	Scf
4. Chaparral (hard chaparral)	Sc
5. Scrub-Hardwood	Shw
F. Forest	F
1. Hardwood	Fhw
2. Mixed Evergreen	Fme
3. Coniferous	Co
a. Redwood	Co_{rw}
b. North Coast	Co_{nc}
c. Douglas Fir	Co_{df}
d. Pine Cypress	Co_{pc}
G. Riparian	R
H. Agriculture	A

TABLE 6.5. NATURAL VEGETATION CLASSIFICATION UTILIZED FOR PRELIMINARY ERTS-1 MAPPING OF SAN JOAQUIN VALLEY SITES

A. Mesquite

B. Lowland Types

C. Sagebrush

D. Desert Saltbush

E. Agriculture

TABLE 6.6. VEGETATION CLASSIFICATION USED FOR VEGETATION DATA BASE MAPPING OF THE CENTRAL REGION TEST SITE

1. Barren
2. Strand
3. Marsh
4. Grassland
5. Soft Chaparral
6. Hard Chaparral
7. Scrub
8. Scrub Grassland
9. Scrub Hardwood
10. Woodland Savanna
11. Hardwood Forest
12. Coniferous Forest
13. Desert Scrub
14. Riparian
15. Agriculture
16. Urban
17. Waterbodies

categories are very similar and reflect the land use potential of the site.

The test area includes a great diversity of vegetation associations, ranging from the dense Monterey Pine (*Pinus radiata*) stands in the Monterey area to the extensive areas of saltbush (*Atriplex* sp.) in the San Joaquin Valley. There is also considerable variability within general physiognomic groupings such as the "coniferous forests." In the latter case, the composition varies from *Pinus radiata* in the north to *Pinus monophylla*, *Pinus ponderosa*, *Abies concolor*, and *Pseudotsuga macrocarpa* in the mountainous areas south of Bakersfield. Owing to this considerable diversity of vegetation types, the region serves as an excellent test site for determining the utility of ERTS-1 imagery for making differentiations both between and within different physiognomic vegetation associations.

The actual interpretation and mapping of the vegetation was done by three skilled interpreters, who were familiar with the characteristic vegetation types in the area. The interpretation was done on the original black-and-white, 1:1,000,000 scale, 9.5 x 9.5 inch transparencies. For each scene or area imaged on a given frame, at least two bands (generally bands 5 and 7) were interpreted in concert to fully utilize the significant information from both the visible and infrared portions of the spectrum. Two or more dates were also utilized for each scene to exploit seasonal variations that might improve identification and delineation accuracy. The actual identification of the different vegetation associations was based on a combination of tonal differences, macrotextural differences, and locational data on the ERTS-1 imagery. The interpretation was carried out utilizing hand magnifiers and Zeiss stereoscopes (when reinforcement and/or combination of images was desired, or when limited stereoscopic viewing was possible). The original mapping was completed on individual acetate overlays and later transferred to a single map base.

The minimum mapping unit, i.e., the smallest area that was classified as to given vegetation association, was 2.641 square kilometers. At a scale of 1:1,000,000, a land area of 2.641 square kilometers equals approximately 0.026 square centimeters on the image. Accordingly, it was felt that units smaller than 2.641 square kilometers would be comparatively insignificant, and unmappable, at a scale of 1:1,000,000. As a consequence of the selection of this minimum mapping unit, certain vegetational features (such as the kelp concentrations and areas of riparian vegetation) were too limited in areal extent to merit mapping at the ERTS-1 scale. However, it has been possible to map and determine the areal extent of these areas (as documented in previous reporting periods), using five to ten times (5x to 10x) enlargements of the ERTS-1 imagery. These findings will be summarized in the final report.

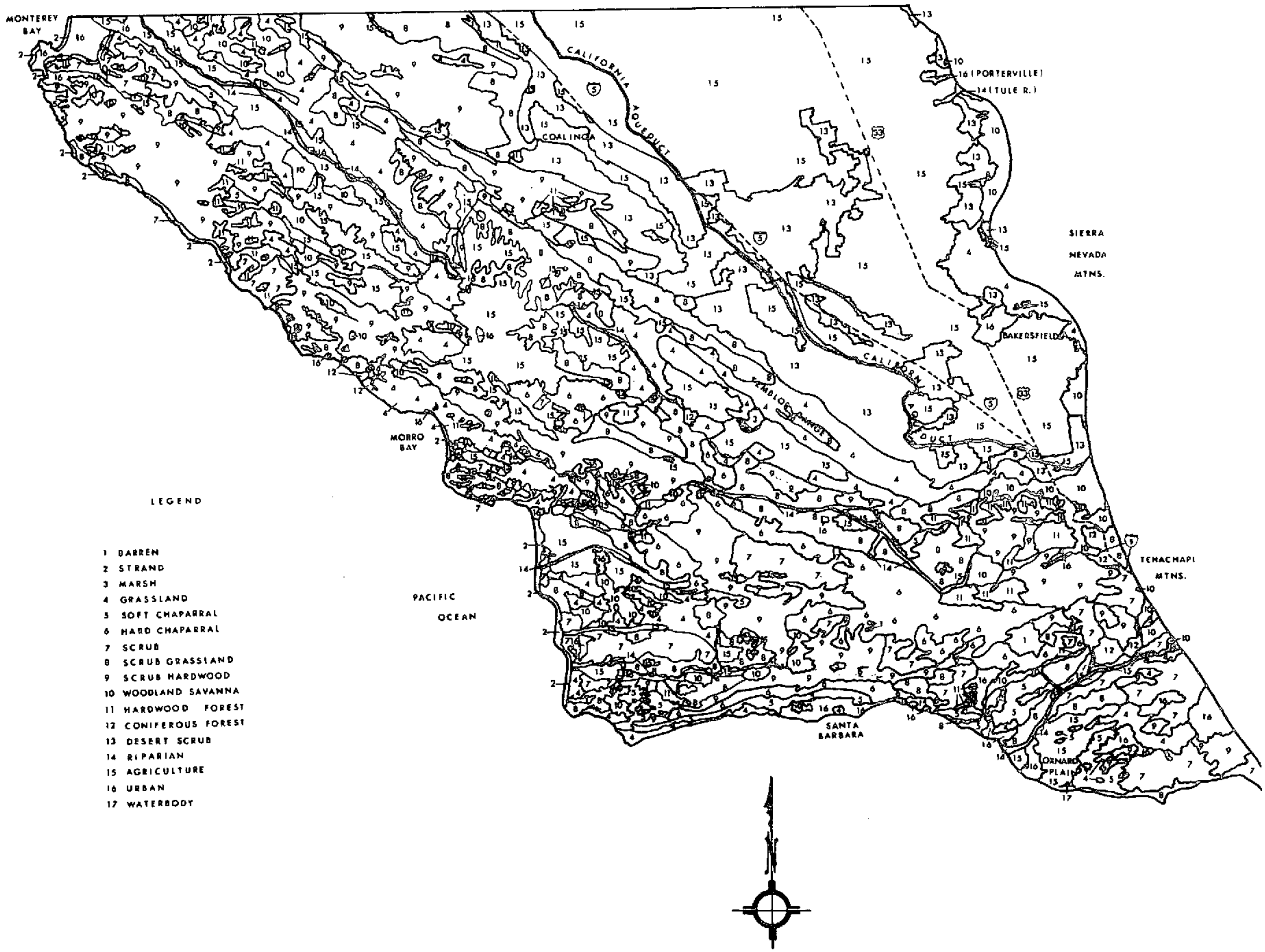
Upon completion, the 1:1,000,000 data base map of the vegetation associations of the Central Region test site was evaluated by: (1) comparing the mapping accuracy (i.e., delineation of vegetation boundaries) with similar maps constructed utilizing 1972 NASA high altitude photography; (2) viewing analogous areas on color and color-infrared high altitude photography (at scales of 1:60,000, 1:120,000 and 1:390,000) on which a majority of the mapping categories could be consistently identified; and (3) acquiring ground truth for selected areas to determine variable species composition in the major associations throughout the region.

6.4.2 Results

The results of the vegetation mapping of the entire Central Region test site (see Figure 6.3) indicate that most of the major physiognomic vegetation groupings (e.g., forest, scrubland, grassland, savanna, etc.) can be mapped accurately using multidate, multiband ERTS-1 imagery. By utilizing ERTS-1 data for mapping such extensive areas (on a regional scale), it will be possible to rapidly update valuable vegetation resource data. With varying degrees of accuracy, 17 different vegetation units could be identified. Each of these different vegetation units represents basic differences in site characteristics. In most cases these may indicate either the development potential of an area or the effect, favorable or unfavorable, that man has had on the area.

The time savings resulting from the interpreter's ability to continuously map large areas eliminates the difficulties commonly encountered when utilizing conventional aerial photomosaics. The time required to map the entire 52,213 square kilometer area was approximately 10 man-days. A large proportion of this time included familiarization with the small scale imagery, the selection of optimal dates, and general familiarization with the variable tonal characteristics of the different vegetation types over time. Given present expertise, the completion of vegetation maps of similar size, scale,

Figure 6.3. CENTRAL REGION VEGETATION DATA BASE



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and areal extent should require no more than 3-5 man-days.

The major problem encountered in working with the ERTS-1 imagery was the difficulty in differentiating between woody and arborescent vegetation, such as hard chaparral, hardwood forests, and coniferous forest. Based on tonal variations alone, and depending on the band of MSS imagery studies, these associations tend to range from dark grey to black and are very difficult to differentiate. Nevertheless, some differentiations can be made based on geographical location (i.e., proximity to the coast or location in mountainous areas). The Cross-Evaluation Chart (Table 6.7) shows the relative ease of differentiating between the vegetation associations. The ratings are based not only on tonal differences and locational factors, but also on the use of the multidate and multiband aspects of ERTS-1 images. The ratings indicate that there is reasonably high accuracy for differentiating between some of the individual categories. However, when one attempts to differentiate a given category from all of the other possible categories, the identification accuracy is considerably reduced owing to the similar signature and geographic distributions of different vegetation associations.

Table 6.8 provides a list of vegetation associations, or groups of vegetation associations, which can be accurately differentiated from each other, but within each group correct identification is generally very difficult. The major difficulty is in differentiating between woody vegetation types (comprised of various species of trees and woody shrubs). Grassland associations, or areas having relatively high concentrations of grass, can generally be easily differentiated from

TABLE 6.7. CROSS-EVALUATION CHART SHOWING THE RELATIVE EASE OF DIFFERENTIATING BETWEEN VEGETATION ASSOCIATIONS ON ERTS-1 IMAGERY BASED ON INTERPRETATIONS PERFORMED USING MULTIBAND-MULTIDATE ERTS-1 DATA

	Barren	Strand	Marsh	Grassland	Soft Chaparral	Hard Chaparral	Scrub	Scrub Grassland	Scrub Hardwood	Woodland Savanna	Hardwood Forest	Coniferous Forest	Desert Scrub	Riparian	Agricultural	Urban	Waterbodies	Composite
Barren		+	++	++	++	++	++	++	++	++	++	++	+	++	++	++	++	++
Strand	+		++	++	++	++	++	++	++	++	++	++	++	++	++	+	++	++
Marsh	++	++		++	-	+	+	++	++	++	++	++	++	+	++	++	-	-
Grassland	++	++	++		++	++	++	-	++	+	++	++	+	++	+	++	++	++
Soft Chaparral	++	++	++	++		--	--	+	+	+	-	+	++	+	++	++	++	--
Hard Chaparral	++	++	+	++	--		--	+	--	++	--	-	++	+	++	++	++	--
Scrub	++	++	+	++	--	--		+	--	+	--	-	++	++	++	++	++	-
Scrub Grassland	++	++	++	-	+	+	+		+	--	++	++	-	++	++	++	++	-
Scrub Hardwood	++	++	++	++	+	--	--	+		+	--	--	++	-	++	++	++	+
Woodland Savanna	++	++	++	+	+	++	+	--	+		+	++	+	++	++	++	++	+
Hardwood Forest	++	++	++	++	-	--	--	++	--	+		--	++	-	++	++	++	--
Coniferous Forest	++	++	++	++	+	-	-	++	--	++	--		++	+	++	++	++	--
Desert Scrub	+	++	++	+	++	++	++	-	++	+	++	++		++	++	++	++	+
Riparian	++	++	+	++	+	+	++	++	-	++	-	+	++		-	++	++	-
Agricultural	++	++	++	+	++	++	++	++	++	++	++	++	++	-		+	++	++
Urban	++	+	++	++	++	++	++	++	++	++	++	++	++	++	+		++	++
Waterbodies	++	++	-	++	++	++	++	++	++	++	++	++	++	++	+	++		++

++ Excellent Differentiation (approximately 100%)
+ Good Differentiation (limited confusion)
- Limited Differentiation (often confused)
-- Poor Differentiation (undifferentiable in most cases)

TABLE 6.8. VEGETATION ASSOCIATIONS OR GROUPS OF VEGETATION ASSOCIATIONS WHICH HAVE SIMILAR SPECTRAL SIGNATURES AND LOCATIONAL CHARACTERISTICS

I

Barren

II

Strand

III

Marsh
Waterbodies

IV

Grassland

V

Desert Scrub

VI

Woodland Savana
Scrub Grassland

VI

Woodland Savana
Scrub Grassland

VII

Soft Chaparral
Hard Chaparral
Scrub
Scrub Hardwood
Hardwood Forest
Conifer Forest

VIII

Riparian

IX

Agricultural

X

Urban

The members within each group are generally very difficult to differentiate from one another.

the more woody associations. Despite the difficulty of differentiating between woody vegetation associations, it should be emphasized that ten distinct vegetation categories can be identified with a relatively high degree of accuracy.

The most significant of the results of the vegetation mapping using ERTS-1 imagery may be summarized as follows: (1) the realization of its value as a mapping base on which accurate, continuous boundaries of major vegetation units can be delineated; (2) the ability to improve identification and delineation results with multidate imagery received on a regular basis; and (3) the use of ERTS-1 imagery for the selection of optimal areas for verification of interpretation results, either by utilizing limited conventional aerial photography or ground reconnaissance techniques.

Vegetation data base maps at the scale afforded by ERTS-1 provide valuable information about site characteristics and the potential for future development. They give the planner an excellent idea of the relative amount of open space compared to areas that are presently used for agricultural, urban, or industrial purposes. The vigor and density of vegetation also serve as measures of the intensity of human interference with the natural environment. For example, it was possible on the ERTS-1 imagery to observe a considerable difference between the nature of the vegetation communities within the Los Padres National Forest and those areas outside the area which are subjected to more intensive use.

6.4.3 Summary and Future Research

The completion of the vegetation data base map for the entire 52,213 square kilometer Central Region area showed that the use of multidate, multiband ERTS-1 imagery provided for rapid and accurate delineation of major vegetation associations. In many cases, the identification of the different vegetation associations was performed with an accuracy comparable to that obtainable utilizing conventional high altitude aerial photography. Some vegetation associations are not consistently differentiable, but this may be improved with the acquisition of additional seasonal ERTS-1 imagery. Furthermore, with limited ground or light aircraft reconnaissance, the use of ERTS-1 imagery should prove to be the most efficient and accurate means of obtaining natural vegetation data on a broad regional basis.

Future research leading to the final analysis of the usefulness of ERTS-1 imagery for vegetation mapping will entail: (1) a more intensive look at all dates and bands for spectral signature differences that may provide greater discrimination between problem vegetation associations; and (2) a tabulation and discussion of the procedures and techniques that should be followed to obtain maximum results when utilizing ERTS-1 imagery for vegetation mapping on a broad regional basis.

6.5 SIGNIFICANT RESULTS

Experimental results during this reporting period primarily pertain to the construction of data bases for land use, drainage, and vegetation in the Central Region of California. Results indicate that, for the most part, ERTS-1 imagery is an efficient and accurate data source

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D ______
N ______
ID ______

DATE ______

PRINCIPAL INVESTIGATOR ______

GSFC ______

ORGANIZATION ______

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Land Use	Geology	Veg.	DESCRIPTORS
1200 18123M				Clouds - Haze - Snow
1200 18125M				Clouds
1200 18132M	X	X	X	Clouds
1219 18182M				Clouds
1220 18241M				Clouds
1235 18075M	X	X	X	Excellent Image
1235 18082M				Island
1235 18073M	X	X	X	Excellent Image
1218 18130M				Clouds
1218 18133M				Clouds
1218 18124M				Clouds
1238 18242M	X	X	X	
1237 18183M				Haze
1237 18190M				Clouds
1255 18190M	X	X	X	Bay
1255 18183M	X	X	X	Bay
1236 18131M	X	X	X	Haze
1236 18125M	X	X	X	
1253 18082M				Island
1253 18075M	X	X	X	
1230 18134M	X	X	X	Haze
1234 18023M				Islands
1234 18021M	X	X	X	
1215 17564M	X	X	X	
1253 18073M	X	X	X	
1002 18140M				Color
1217 18081M				Clouds - eddy
1217 18074M	X	X	X	
1217 18072M	X	X	X	
1216 18020M				Clouds
1233 17565M				Clouds
1254 18125M	X	X	X	
1254 18131M	X	X	X	
1254 18134M	X	X	X	

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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GSFC 37-2 (7/72)

for broad scale regional mapping requirements. General land use categories can be identified, located, and mapped within reasonable limits of accuracy. Drainage networks and basins can be mapped from ERTS-1 data with sufficient accuracy to permit updating of U.S.G.S. 1:250,000 topographic maps. Vegetation associations can be reliably delimited, although some problems exist with woody vegetation types. These problems can be mitigated through selective use of ground or light aircraft reconnaisance. The success of these investigations is attributable to the multiband opportunity provided by ERTS-1 to view phenomena that are highlighted in different bands, and its multidate capability for viewing certain phenomena at their most photogenic seasons of the year. Perhaps most significantly, it is estimated that each of these data base maps (encompassing an area of some 52,213 square kilometers) could be constructed for a different time period in approximately one man-week.

Chapter 7

USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (UN314)

Co-investigator: Leonard W. Bowden
Department of Geography, Riverside Campus

7.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

The project for the preceding two months has continued the study involving the agricultural inventory of the Imperial Valley. Other studies centering on the California Desert Environment have resulted from a cooperative effort with the Bureau of Land Management, California Desert Program. One study is concerned with the impact of off-road-vehicles on the fragile desert environment. Another study deals with man-made linear features on the Mojave Desert as detected from ERTS-1 imagery. Details of these studies are given below.

7.1.1 Agricultural Inventory in the Imperial Valley

The project to determine the feasibility of producing crop inventories from ERTS-1 imagery utilizing the Imperial Valley as a test site is continuing with promising results. Images from the even numbered (36-day) cycles are being interpreted for the status of field conditions (i.e., growing crop, irrigated field, plowed field, or bare fallow field). In developing the computer program to compare the field condition data for the 8,000 plus fields with the related crop calendar it was found that interpretation from the four different images resulted in some errors.

Preliminary testing of the computer identification system has shown that a computer edit program had to be written to edit all interpreted data. The edit program reviews the field conditions detected for an individual field for at least four ERTS cycles to determine if the sequence of field conditions could be logically correct. It was discovered that some fields were interpreted to show the field changing from a growing condition to a plowed condition back to a growing condition, a situation impossible in this time period. The computer edit program will detect any such possible errors and will request reinterpretation. In most instances we are finding that the cycle containing the error was either misinterpreted or an error occurred as transcription of the data in the coding process.

The crop identification program to compare the field condition to the crop calendar has been written, but not fully tested. In the above example, if all four cycles (August 26, October 1, November 6 and December 12) showed a field condition of a growing crop, then the identification would be alfalfa since that is the only possible crop that would produce such an interpretation. Initial test of the fields for which we have ground truth resulted in 100 percent accuracy for alfalfa identification. This accuracy is compared to the Apollo 9 single image interpretation accuracy of only 42 percent for alfalfa. Other fall crops of sugar beets, lettuce, melons, grains, and rye grass are showing about 75 percent accuracy on the four fall cycles. This accuracy will be improved by either inclusion of two more cycles, or the selection of four winter/spring cycles.

A secondary result from the crop inventory project has been to produce data from which irrigated water demand can be estimated for the succeeding 36-day period. Preliminary results, using very rough average monthly demands, indicate that water demands can be estimated to within 4 percent of 160,000 acre-feet. Full details of the water estimates will be given in the final report.

7.1.2 Study of Land Surfaces in the Mojave Desert

Investigations focusing on the operation of off-road-vehicles in the Mojave Desert were originally focused on the Barstow to Las Vegas motorcycle race. To assess the effects of the race upon the environment, emphasis was placed upon evaluating the different responses various desert surfaces have to vehicle activity. Initial enhancement (using the I^2S color combiner) of ERTS-1 imagery was mapped onto 1:250,000 and 1:62,500 USGS topographic sheets and then the results were field checked. Field reconnaissance has shown that textural/slope changes can be revealed on the enhanced imagery. Unfortunately, due to lack of equidensity film, research is confined to the one image for which density slices have been made. Results to date are more than encouraging.

7.1.3 Mojave: Man-Made Linear Features

ERTS imagery of the Mojave Desert has provided considerable insight into the impact of linear human constructions upon pre-existing surface patterns. On this imagery such features as roads, railroad lines, and aqueducts can be seen to have had a great impact upon drainage patterns, vegetation distribution, and the formation of salt patterns upon playas.

Ground observation, however, does not adequately reveal the extent of this impact.

By damming and channeling surface and subsurface water flow, these linear constructions have increased rates of erosion in some areas and decreased them in others. Also, certain areas have been favored for plant growth. This situation is especially true where such linear features cross alluvial fans. Even though new features have had profound effects upon surface patterns, older ones, like railroads constructed during the last century, have had the greatest impact. Possibly the most spectacular such impact occurs southwest of Amboy, California where the old route of the Southern Pacific and a highway which paralleled it have each dramatically offset drainage patterns.

7.1.4 Hidden Valley

High level aerial photography (December 1972) has revealed linear surface patterns extending for several miles around the periphery of Hidden Valley, Nevada approximately 25 miles south of Las Vegas (scale, 1:130,000).

At this time, the nature of these lines is not certain. It was initially believed that they were the product of Indian activity in the area. That thesis has not yet been disproven. Moreover, ground investigation has revealed several signs of aboriginal activity in the vicinity. Among these are apparent antelope blinds and stone rings, probably house rings.

The nature of the lines themselves is, nevertheless puzzling. While they appear continuous on the imagery, no continuous lines can be seen on the ground. Apparently the lines themselves are comprised of dead creosote bushes which have been colonized by pioneer plant species. Thus, what appear as lines on the imagery appear on the ground as broad bands in which these plant communities exist at scattered points.

Several facts about these lines have become apparent from interpretation of the imagery. Eighteen in all have been identified in the best preserved series. While they are parallel, they are curvilinear but do not follow contour lines as would a former lake shoreline. Moreover, these lines stop abruptly at the edges of several alluvial fans, resuming again on the far side. The surfaces of these fans have not been disturbed for several thousand years. Thus, these lines either predate the fans or never existed upon them. If the former situation obtains, the lines can be assumed to be at least ten thousand years old.

The extreme unlikelihood of an archaeological find of this magnitude leads one to suspect that these lines are the product of some old range management program. The present leasee of the land, Harold Knight, will be contacted to determine the recent history of Hidden Valley. Even if it is determined that these lines are the products of recent activity, it is interesting and valuable to know that surface patterns which are not visible on the ground can be seen clearly on U-2 imagery.

7.1.5 Disjunct Fluvial Transport Patterns in the Colorado River Delta as Interpreted from ERTS-1 Imagery

Cursory examination of ERTS-1 imagery of the Colorado Delta for two dates, September 12 and December 29, 1972 reveals differences in sediment transport patterns in the waters of the Northern Gulf of the California Delta region. Initial impression of these differences leads one to believe that what is seen is either surface phenomena or the bottom configuration of the Colorado River Delta. The discontinuities might be attributed to any one or a combination of variables. These variables could conceivably be: (1) local storm activity and related precipitation; (2) agricultural activity; (3) tidal flow or stage; (4) currents in the gulf; (5) thermal differences at the interfaces of any surface and subsurface discontinuities; and/or (6) thermal mixing of the fresh and saline water at the delta.

Such examination of ERTS-1 imagery of the Colorado Delta and Gulf of California coastal region leads to certain possible generalizations about agricultural activity and, in turn, some inference can be made about relative amounts of precipitation for that region. These elements combine to modify fluvial transport patterns in the delta region significantly. Examination of sequential imagery of the delta could be used to substantiate any interpretation of agricultural activity made from ERTS imagery of the Lower Colorado River. At this time more intensive research into the variables affecting delta sedimentation system is necessary before any extensive application of the imagery is made. Lack of access to tidal information and to data regarding temperatures of the Colorado River and the Gulf of California, and likewise to scant data available on mixing rates in the delta, makes any conclusions or statements unsupportable. Initial impressions realized from the imagery are encouraging, however, and it is felt that further research on this aspect of the Colorado River water system is warranted.

7.2 WORK FOR NEXT REPORTING PERIOD

Work toward completion of the Agricultural Inventory Automated System: preparation of the final report is to include all previous work accomplished under the contract and reporting of as much of the agricultural inventory system that is completed by the final reporting date of July 15, 1973.

Chapter 8

DIGITAL HANDLING AND PROCESSING OF ERTS-1 DATA (UN 645)

Co-investigator: V. R. Algazi
Contributors: D. J. Sakrison, J. Schriebman, W. Avery
B. Romberger, F. Samulson, W. Dere
Department of Electrical Engineering and Computer Sciences
Davis and Berkeley Campuses

8.1 INTRODUCTION

The investigation of digital handling and processing of ERTS-1 data centers on problems of electronic image enhancement and multi-sensor data combination.

Our work emphasizes man-machine interaction and uses a versatile digital image processing facility, a set of basic programs for image enhancement and multi-image combination and display. The work is designed to meet three broad objectives:

1. To examine the fundamental issues underlying the extraction of information by visual study of images. These issues involve the determination and study of the statistics of the available data and of properties of human vision in the spectral and spatial domain. A further step then matches the presented pictorial data to the perceptual properties of the observer.

2. To provide other participants in our intergrated study with images which combine and electronically enhance various spectral components in such a fashion that interpretation of the data is eased.

3. To consider the application of the data to specific problems

of interest in our integrated study, such as the mapping of vegetation types, the determination of hydrology parameters, the determination of water quality, etc. For each application we electronically enhance the digital data so that the subset of data relevant to the application is represented in some optimal fashion as a false color image. Our primary source of data is in the form of computer compatible tape.

8.2 PROCEDURES AND RESULTS

8.2.1 Enhancement of ERTS-1 Data

We have explored more fully the application of the technique on image enhancement described in our Progress Report of January 31, 1973 to several problems of interest to other participants of the integrated study. These include the following:

1. Enhancement and processing of ERTS-1 data to improve the visibility of sediments, pollutants and other indicators of water quality. This fairly extensive work, of interest to Dr. Robert Burgy, was carried out in consultation and cooperation with Jean Malingreau, also of the Department of Water Sciences and Engineering at the University of California, Davis.

2. Enhancement of ERTS-1 imagery to assist in the delineation and inventory of earth resources in wildlands and agricultural areas of northern California. This work was done to assist Don Lauer and Bill Draeger of the Forestry Remote Sensing Laboratory.

8.2.2 Pseudocolor Display Scales

A discussion of a rational choice of pseudocolor scales was presented in the January 31, 1973 Progress Report. Significant progress has been made relative to this matter and examples have been obtained which demonstrate in a striking manner the advantages of using a properly chosen scale.

This work, and the basic enhancement algorithm of 3.2.1, are being submitted for publication.

8.2.3 Multidate Data Combination

We have done some preliminary work on combining the data obtained at the same geographical location on different passes of the ERTS-1 satellite. The registration achievable from bulk MSS data is sufficiently good for small areas (512 x 512 picture elements) to allow the study of temporal variations of radiometric response. Some preliminary results have been obtained in water. Substantially more work is needed.

8.2.4 Multispectral Data Combination

A problem of continuing interest in remote sensing is the rational use of multispectral data. The problem is inherently related to the limitation of a human observer to comprehend and correlate the information provided by too many sensors. This problem is already apparent with ERTS-1 data recorded in four spectral bands. The conventional solution used by NASA is to provide color composites of either MSS bands 4, 5 and 6 or MSS bands 4, 5 and 7. We have undertaken a fairly long-range, systematic study of this problem by considering in turn the following two important points:

1. The correlation and redundancy of the data from one spectral band to another.

2. The combined limitation of the reproduction media of the human observer to discriminate information presented in image form.

The second point is related to our study of perceptual scales. More work is planned in this area, but we are currently limited in our ability to obtain quantitative, reproducible color reproductions. The precision CRT display currently being brought into operation will give us better control of photographic products.

A fairly extensive report and illustrative examples will be presented in the final ERTS-1 report.

8.3 ERTS-1 DATA PROBLEMS: STRIPPING

In some of the images distributed by NASA the stripping effect, due to different responses of the sensors in the multispectral scanner, is quite apparent. This effect is greatly magnified as one tries to enhance the images digitally for visibility in the water, since the range of useful sensor outputs is then quite narrow and data errors are more significant. It is possible to bring about some improvement of image quality by equalizing the sensors response on the basis of the statistics of the received data.

An extensive report on our technique is in preparation. Information on our approach to data correction has been supplied to other principal investigators using ERTS-1 data.

Chapter 9

USE OF ERTS-1 DATA IN THE EDUCATIONAL AND APPLIED RESEARCH PROGRAMS OF AGRICULTURAL EXTENSION (UN326)

Co-investigator: William E. Wildman
Agricultural Extension Service, Davis Campus

9.1 PROCEDURES AND RESULTS

9.1.1 Plumas County Land Use

A remote sensing workshop was held in Plumas County for the farm advisor, County Planning Director and his assistant, and representatives from the California Division of Forestry and the University of California Forestry Summer Camp. These gentlemen are interested in using multistage remote sensing data in revising the general plan for Plumas County, a livestock and timber producing county whose largest future cash crop is likely to be recreation.

The interest of this group led to an additional full day's workshop at Berkeley led by the staff of the Forestry Remote Sensing Laboratory. Since this laboratory has used the Feather River watershed as a test site for both aircraft and ERTS imagery, the County Planner has a unique opportunity to obtain much useful data.

The farm advisor has ordered multidate ERTS color infrared diazochrome composites from our Visual Aids unit, and is working with the Plumas County Planner to apply these to broad land use planning.

9.1.2 Color Infrared Composite Mosaic of California

Barry Brown of the land use section of the California Department of

Water Resources is making a color infrared mosaic of the entire state and has borrowed our 9 x 9 inch ERTS positives from which to make color negatives.

9.2 WORK PLANNED FOR NEXT REPORTING PERIOD

We are continuing distribution of 1:1,000,000 black-and-white reproductions of the number 5 MSS band to all county Extension offices. In addition, we want to prepare a black-and-white mosaic of the entire state of California and make it available to the county offices.

Chapter 10

THE USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION AND MAPPING OF SALT-AFFECTED SOILS IN CALIFORNIA (UN327)

Co-investigator: Gordon L. Huntington
Department of Soils and Plant Nutrition, Davis Campus

10.1 PROCEDURES AND RESULTS

During this reporting period two extensive flights were conducted (on April 5, 1973 and April 24, 1973) covering the western San Joaquin Valley and the Dozier area south of Dixon, California. Low oblique ground truth images in color and color infrared were taken. On site field observations of the Dozier area were conducted in conjunction with the ERTS-1 overpass.

Continuing laboratory studies entail the inventorying and indexing of images and the production of diazochrome composite images. Interpretation of present images is restricted due to excessive cloud cover.

The geometric and random number controlled colored transparency patterns described in the Type 2 report of this project have been completed for the seven vegetation cover classes and are presently being interpreted and correlated with the ERTS 9 x 9 inch diazochrome composites.

The ERTS imagery received during this period has had restricted usefulness due to excessive cloudiness. As stressed in this project's Type 2 report the vernal period, principally cycles 14, 15, and 16, will be the most productive for extensive interpretations of salt-affected soils but image 1254-18131 is the latest image received to date.

The project work noted above has been supported by California Agricultural Experiment Station funds.

10.2 WORK PLANNED FOR NEXT REPORTING PERIOD

We plan to continue cyclic observation of selected central valley sites, further development and interpretation of vegetative cover patterns as correlated to field patterns on diazochrome composites, and investigation of other possible positive-negative combinations of bands 4, 5 and 7 for maximizing contrasts on the diazochrome composites.